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Patents Act 1990

PROVISIONAL SPECIFICATIPONS

For the invention entitled:

Aptitude Testing Through Brain Activity Measures

The invention is described in the following statement:

APTITUDE TESTING THROUGH BRAIN ACTIVITY MEASURES

APTITUDE TESTING

The present invention relates generally to the field of aptitude testing, including apparatus and methods for testing the aptitude of subjects to mental tasks and assessing subjects thinking style.

Existing commonly-used aptitude tests attempt to measure a subject's current abilities using a standardised test appropriate to the subject's age, language, culture and educational background. The tests do not necessarily identify potential aptitude in subjects who do not meet a basic requirement of the tests such as a particular educational background or for whom no standardized test exists or is appropriate. For example, as existing tests require a minimum level of knowledge before aptitude can be assessed, those subjects with natural abilities not meeting the minimum requirements would generally not be identified as potential candidates. Furthermore, minorities may consider certain tests to be unfair and discriminatory. There is a need for a new test which can be used to assess potential aptitude as well as current aptitude levels.
Aptitude and thinking style are closely related and thus a test that can identify aptitude can also be used to identify a subjects thinking style. Knowledge of a subjects thinking style can also be used to identify the optimum teaching and training approach for the subject.

United States Patent Nos. 4,955,938 and 5,331,969 (the contents of which are hereby incorporated herein by reference) disclose technique for obtaining a steady state visually evoked potential (SSVEP) from a subject. These patents disclose the use of Fourier analysis in order to rapidly obtain the SSVEP's and changes thereto. It is now appreciated that these techniques can be utilized to measure brain activity and assess the aptitude of an individual. The present invention utilizes SSPT, a brain imaging technique based on the brain's response to a continuous visual flicker or the SSVEP to examine changes in the activity in various brain regions while an individual undertakes a number of

cognitive tasks. It is suggested that cognitive aptitude will be indicated by specific changes in SSVEP amplitude, phase and coherence during a given cognitive task. This has been demonstrated in studies undertaken by the inventor and Ms Joao Neves a PhD student supervised by the inventor. These studies revealed that that different thinking style were associated with different patterns of brain activity. Subjects that score high, on a test of analytical thinking show greater left hemisphere phase advance that is interpreted as greater activation of this area during the analytical task. By contrast, subjects that score low on the test of analytical thinking do not show this patter. In addition, subjects that score high on a test of holistic thinking show greater SSVEP pahse advance at right hemisphere sites. These results are consistent with neuropsychological research indicating a specialised role for the left hemisphere in analytical thinking and the right hemisphere for holistic thinking.

More generally, SSVEP can be used to identify aptitude in specific cognitive domains known to be associated with performance and training aptitude. For example, trainee aircraft pilots need aptitude in visualizing their environment in three dimensions. A test for this ability could involve SSVEP measurements while the subject undertakes the Mental Rotation Task where they are required to rotate images of three dimensional shapes. Specific changes in SSVEP amplitude, phase and coherence are associated with a high aptitude for this task and these changes may be used to identify individuals with a high ability to manipulate three dimensional images. Studies undertaken by the inventor reveal that individuals with a high aptitude for the manipulation of three dimensional images exhibit a greater phase advance at left prefrontal cortical sites and reduced coherence between central and parietal cortical sites. By contrast, subjects with a high ability show increased SSVEP coherence between right prefrontal and central sites during the time that the image was held in short term memory without manipulation.

More particularly, the techniques of the invention can be used in a number of different fields including, but not limited to:

(i) identifying cognitive aptitude in specific domains

(ii) identifying an individual's thinking style and hence the optimum

teaching/training approach.

(iii) identifying the suitability of an individual for specific training;

(iv) identifying the suitability of an individual for specific employment;

More particularly, the invention provides a method of determining the cognitive aptitude of an individual, the method including the steps of:

presenting to the individual a group of cognitive tasks that place demands on various emotional and cognitive domains which include but are not limited to attention, analytical thinking, holistic thinking, verbal thinking, visuo-spatial thinking, working memory, recognition memory, identifying emotional expression;

detecting brain response signals from the subject during presentation of said group of cognitive tasks;

calculating amplitude phase and/or coherence SSVEP responses from said brain response signals;

comparing SSVEP responses from said controlled tasks to SSVEP responses from said test tasks with a data-base of SSVEP responses recorded from individuals with high and low aptitudes in specific domains; and

identifying the subject's thinking style and aptitude for the cognitive domain or task under consideration.

The changes in SSVEP amplitude, phase and/or coherence can be an increase or decrease. Also, the magnitude of the change may vary from case to case. One way of determining whether there has been a significant change in SSVEP amplitude, phase and/or coherence is by reference to statistical analyses where a change is regarded as significant at the $p<0.05$ level where p represents the probability of a Type 1 statistical error (i.e. wrongly rejecting the null hypothesis). Statistical significance can be tested using a number of methods including student's t-test, Hotellig's T2 and the multivariate permutation test. For a discussion of these methods used to analyse the SSVEP see Silberstein R.B., Danieli F., Nunez P.L. (2003) Frontoparietal evoked potential synchronisation is increased during mental rotation. Neuroreport, 14:67-71, Silberstein

R.B., Farrow M.A., Levy F., Pipingas A., Hay D.A., Jarman F.C. (1998). Functional brain electrical; activity mapping in boys with attention deficit hyperactivity disorder. Archives of General Psychiatry 1998; 55:1105-12.

The invention will now be further described with reference to the accompanying drawings, in which:

FIGURE 1 is a schematic diagram of a system of the invention;

FIGURE 2 is a schematic view showing in more detail the manner in which visual flicker signals are presented to a subject.

Figure 1 schematically illustrates a system 20 for determining the response of a subject 6 to a cognitive task which can be presented to the subject 6 on a video screen 1 and loudspeaker 11. The system includes a computer 2 which controls various parts of the hardware and also performs computation on signals derived from the brain activity of the subject 6, as will be described below. The computer 2 also holds the cognitive task which can be presented to the subject 6 on the screen 1 and/or through the loudspeaker 11

The subject 6 to be tested is fitted with a helmet 11 which includes a plurality of electrodes for obtaining brain electrical activity from various sights on the scalp of the subject 6. The helmet includes a visor 8 which includes half silvered mirrors 17 and 18 and LED arrays 19 and 21, as shown in Figure 2. The half silvered mirrors are arranged to direct light from the LED arrays 19 and 21 towards the eyes of the subject. The LED arrays 19 and 21 are controlled so that the light intensity there from varies sinusoidally under the control of control circuitry 5. The control circuitry 5 includes a waveform generator for generating the sinusoidal signal. The circuitry 5 also includes amplifiers, filters, analogue to digital converters and a USB interface for coupling the various electrode signals into the computer 2.

The system also includes a microphone 9 for recording voice signals from the subject 6. The microphone 13 is coupled to the computer 6 via a microphone interface circuit 10. The system also includes a switch 4 which can be manually operated by the subject as a part of the response to the cognitive task. The switch 3 is coupled to the

computer 2 via a switch interface circuit 7.

The computer 2 includes software which calculates SSVEP amplitude phase and/or coherence from each of the electrodes in the helmet 7.

Details of the hardware and software required for generating SSVEP are well known and need not be described in detail. In this respect reference is made to the aforementioned United States patent specifications which disclose details of the hardware and techniques for computation of SSVEP. Briefly, the subject 6 views the video screen 1 through the special visor 12 which delivers a continuous background flicker to the peripheral vision. The frequency of the background flicker is typically 13Hz but may be selected to be between 3Hz and 50Hz. Brain electrical activity will be recorded using specialised electronic hardware that filters and amplifies the signal, digitises it in the circuit 9 where it is then transferred to the computer 6 for storage and analysis. SSPT is used to ascertain regional brain activity at the scalp sites using SSPT analysis software.

The topographic distribution of the SSVEP amplitude, SSVEP phase and SSVEP coherence during the performance of the cognitive tasks will be correlated with the aptitude and thinking style of the subject. The cognitive tasks will be presented on the video monitor 1 and/or via the loudspeaker. Subjects will be required to make a response that may comprise a button push or a verbal response.

Verbal responses by the subject associated with a cognitive task will be picked up via microphones 9. The audio signals will be appropriately amplified, filtered and digitised via interfaces 10 and stored as sound files on the computer 2. This enables the timing of the verbal responses to be determined within an accuracy of 10 microsecond. Alternatively, the subject may respond to the cognitive task via a motor response such as a button push via a microswitch 8 that is interfaced with the computer 2 via interface circuit 9. In all cases, the precise timing of all events presented to the subject 6 are preferably determined with an accuracy of no less than 10 microseconds.

As mentioned above, the visor 8 includes LED arrays 19 and 21. In one embodiment, the light there-from is varied sinusoidally. An alternative approach utilises pulse width modulation where the light emitting sources are driven by 1-10Khz pulses where the pulse duration is proportional to the brightness of the sight emitting sources. In this embodiment, the control circuitry 5 receives a digital input stream from the computer 6 and outputs pulse width modulated pulses at a frequency of 1-10Khz. The time of each positive going zero-crossing from the sinusoidal stimulus waveform is determined to an accuracy of 10 microsecond and stored in computer memory 2.

Brain electrical activity is recorded using multiple electrodes in helmet 11 or another commercially available multi-electrode system such as Electro-cap (ECI Inc., Eaton, Ohio USA). The number of electrodes is normally not less than 16 and normally not more than 256, typically 64.

Brain activity at each of the electrodes is conducted to a signal conditioning system and control circuitry 5. The circuitry 5 includes multistage fixed gain amplification, band pass filtering and sample-and-hold circuitry for each channel. Amplified/filtered brain activity is digitised to 16 bit accuracy at a rate not less than 300Hz and transferred to the computer 2 for storage on hard disk. The timing of each brain electrical sample together with the time of presentation of different components of the cognitive task are also registered and stored to an accuracy 10 microseconds.

SSVEP amplitude, phase and coherence

The digitised brain electrical activity (EEG) together with timing of the stimulus zero crossings enables one to calculate the SSVEP from the recorded EEG or from EEG data that has been pre-processed using Independent Components Analysis to remove artefacts and increase the signal to noise ratio. [Bell A.J. and Sejnowski T.J. 1995. An information maximisation approach to blind separation and blind deconvolution, Neural Computation, 7, 6, 1129-1159; T-P. Jung, S. Makeig, M. Westerfield, J. Townsend, E. Courchesne and T.J. Sejnowskik, Independent component analysis of single-trial event-

related potential Human Brain Mapping, 14(3):168-85,2001.]

Calculation of SSVEP amplitude and phase for each stimulus cycle. Calculation accomplished used Fourier techniques using equations 1.0 and 1.1 below.

$$a_n = \frac{1}{S\Delta\tau}\sum_{i=0}^{S-1} f(nT + i\Delta\tau)\cos\left(\frac{2\pi}{T}(nT + i\Delta\tau)\right)$$

$$b_n = \frac{1}{S\Delta\tau}\sum_{i=0}^{S-1} f(nT + i\Delta\tau)\sin\left(\frac{2\pi}{T}(nT + i\Delta\tau)\right)$$

Equation 1.0

Calculation of SSVEP Fourier components where a_n and b_n are the cosine and sine Fourier coefficients respectively. n represents the nth stimulus cycle, S is the number of samples per stimulus cycle (16), $\Delta\tau$ is the time interval between samples, T is the period of one cycle and $f(nT+i\Delta\tau)$ is the EEG signal (raw or pre-processed using ICA).

$$SSVEP_{amplitude} = \sqrt{(a_n^2 + b_n^2)}$$

$$SSVEP_{phase} = \mathrm{a}\tan\left(\frac{b_n}{a_n}\right)$$

Equation 1.1

Calculation of SSVEP amplitude and phase where a_n and b_n are the cosine and sine Fourier coefficients respectively. Amplitude and phase components can be calculated using either single cycle Fourier coefficients or coefficients that have been calculated by integrating across multiple cycles.

Two types of coherence functions are calculated from the SSVEP sine and cosine Fourier coefficients while patients undertake the cognitive task. One will be termed the

SSVEP Coherence ("SSVEPC") and the other, Event Related SSVEP Coherence ("ER-SSVEPC").

SSVEPC

The SSVEP sine and cosine coefficients can be expressed as complex numbers

$C_n = (a_n , b_n)$

where a_n and b_n have been previously defined.

The nomenclature is generalized to take into account multiple tasks and multiple electrodes.

$C_{g,e,n} = (a_{g,e,n} , b_{g,e,n})$

where g= the task number

e= the electrode

n= the point in time

We define the function

$$\gamma_{g,e1,e2} = H_{g,e1,e2} / T_{g,e1,e2}$$

$$H_{g,e1,e2} = \sum_{n=1}^{n=T} C_{g,e1,n} \cdot C^*_{g,e2,n}$$

Where C* is the complex conjugate of C.

and

$$T_{g,e1,e2} = \sqrt{\left(\sum_{n=1}^{T} C_{g,e1,n} \cdot C^*_{g,e1,n}\right)\left(\sum_{n=1}^{T} C_{g,e2,n} \cdot C^*_{g,e2,n}\right)}$$

The SSVEPC is then given by

$$\gamma^2_{g,e1,e2} = \left|H_{g,e1,e2}\right|^2 \Big/ T^2_{g,e1,e2}$$

And the phase of the SSVEPC is given by

ER-SSVEPC

$$\phi_{g,e1,e2} = Tan^{-1}\left(\frac{\mathrm{Im}(H_{g,e1,e2})}{\mathrm{Re}(H_{g,e1,e2})}\right)$$

In this case, the coherence across trials in a particular task can be calculated. This yields coherence as a function of time. The nomenclature can be generalized to take into account multiple tasks and multiple electrodes.

$C_{g,d,e,n} = (a_{g,d,e,n}, b_{g,d,e,n})$

where g= the task number

d= the trial within a particular task, eg a specific response

e= the electrode

n= the point in time

We define the function

$$\gamma_{g,e1,e2,n} = H_{g,e1,e2,n} / T_{g,e1,e2,n}$$

$$H_{g,e1,e2,n} = \sum_{d=1}^{d=D} C_{g,e1,d,n} \cdot C^{*}_{g,e2,d,n}$$

and

$$T_{g,e1,e2,n} = \sqrt{(\sum_{d=1}^{D} C_{g,e1,d,n} \cdot C^{*}_{g,e1,d,n})(\sum_{d=1}^{D} C_{g,e2,d,n} \cdot C^{*}_{g,e2,d,n})}$$

The SSVEPC is then given by

$$\gamma^{2}_{g,e1,c2,n} = \left|H_{g,e1,e2,n}\right|^{2} / T^{2}_{g,e1,e2,n}$$

And the phase of the SSVEPC is given by

$$\phi_{g,e1,e2,n} = Tan^{-1}\left(\frac{\mathrm{Im}(H_{g,e1,e2,n})}{\mathrm{Re}(H_{g,e1,e2,n})}\right)$$

The above equations apply to scalp recorded data as well as brain electrical activity inferred at the cortical surface adjacent to the skull and deeper such as the anterior cingulate cortex. Activity in deeper regions of the brain such as the anterior cingulate or ventro-medial cortex can be determined using a number of available inverse mapping techniques such as BESA, EMSE and LORETA.

While the subject 6 is performing the cognitive and emotional tasks, the visual flicker is switched on in the visor 8 and brain electrical activity is recorded continuously on the computer 2.

At the end of the tests, the SSVEP responses associated with the various tasks can be calculated and separately averaged. For specific tasks, the SSVEP amplitude, phase and

coherence will be compared with a database of results for groups of subjects with high aptitude and specific thinking styles. The comparison will identify the individuals specific thinking style and aptitude. For security purposes, the database can be situated on a remote computer accessed via the internet through a modem 12.

Many modifications will be apparent to those skilled in the art without departing from the spirit and scope of the invention.

DATED this 19th day of August, 2003

SSPT PTY. LTD.
By the inventor
Richard B Silberstein

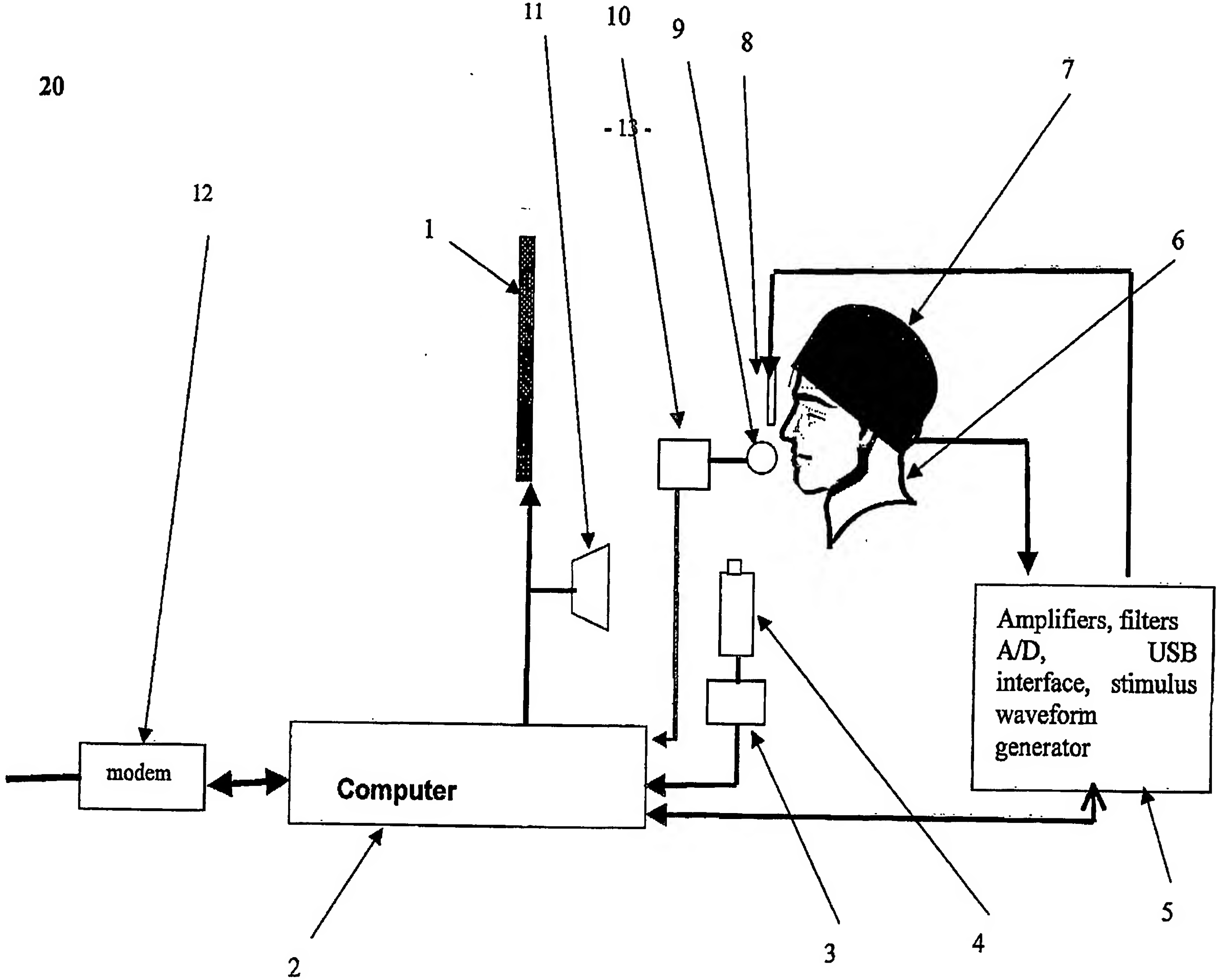
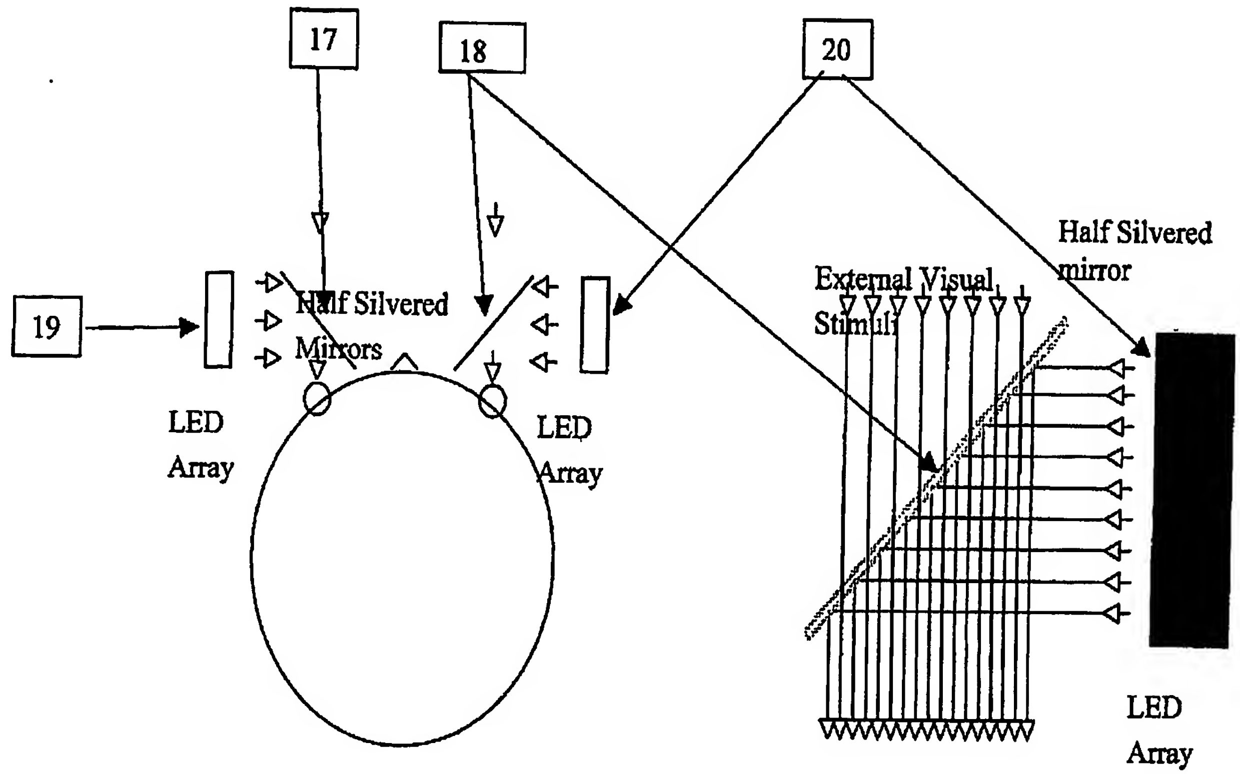

20
11
10
9
8
7
12
1
6
Amplifiers, filters A/D, USB interface, stimulus waveform generator
modem
Computer
2
3
4
5

Fig 1.


17
18
20
19
Half Silvered
Mirrors
LED
Array
LED
Array
External Visual
Stimuli
Half Silvered
mirror
LED
Array